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Notes and Comments

A Reevaluation of the Cold Water Etiology of External Auditory Exostoses

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Hrdlička (1935) conducted one of the earliest systematic studies of external auditory exostoses, noting that they were more prevalent in males and suggested that a combination of heredity and mechanical or chemical irritation might be responsible for stimulating bone growth. Although cited later primarily as a hereditary trait (Berry and Berry, 1967), there is abundant clinical evidence suggesting environmental factors are influential in stimulating the hyperplastic response (DiBartolomeo, 1979; Gregg and Bass, 1970; Harrison, 1962; Kennedy, 1986). Many recent anthropological studies of auditory exostoses have emphasized maritime activities, especially those involving exposure to cold water, as a principal factor in stimulating a hyperplastic response (e.g., Ascenzi and Balisteri, 1975; Frayer, 1988; Kennedy, 1986; Manzi et al., 1991; Standen et al., 1985).

We were presented with the opportunity to study these hyperplastic bony growths when the skull of a single individual from an archaeological site on Useppa Island, Florida (8LL51) was examined as part of a skeletal analysis (Hutchinson, n.d.). Of particular interest in the extremely well preserved skull were multiple bilateral external auditory exostoses (Figs. 1–3). A ^{13}C corrected and calibrated radiocarbon date indicated this individual lived between A.D. 640 and 770 (Hutchinson, n.d.; Marquardt, personal communication). The people who inhabited south Florida at that time were known as the Calusa. Ethnohistoric accounts (Fontaneda, 1945; Hann, 1991; Solís de Merás, 1923) and archaeological evidence such as nets, net weights, cordage, hooks, and other fishing gear (Cushing, 1897; Gilliland, 1975) indicate their lifestyle was oriented primarily around the rich marine environment where they lived. Extensive shell middens dominate Calusa sites and dietary reconstructions using plant and animal remains indicate that the coastal estuaries provided a rich, diverse diet focused on abundant marine resources and terrestrial plants, but not domesticated plants or animals (Russo and Quitmyer, 1996; Scarry and Newsom, 1992; Walker, 1992). Certainly these procurement tasks provided individuals with regular exposure to the aquatic environment, and in an effort to assess the biological costs of the Calusa lifeway, we conducted a histological examination of one exostosis from this individual, compared it with previously reported contemporary clinical specimens, and assessed the hypothesis of cold water as an exclusive etiology.

We removed an exostosis from the right auditory canal with a dental drill for histological examination and photographed it prior to embedding. The exostosis (measuring approximately 2 mm in width and 5 mm in length) was decalcified in nitric acid, embedded in paraffin, sectioned at 10 µm, and stained using hematoxylin and eosin. Microscopic examination (Fig. 4) of the exostosis revealed that the structure exhibits several subperiosteal layers of dense compact bone in a circumscribed area, similar to

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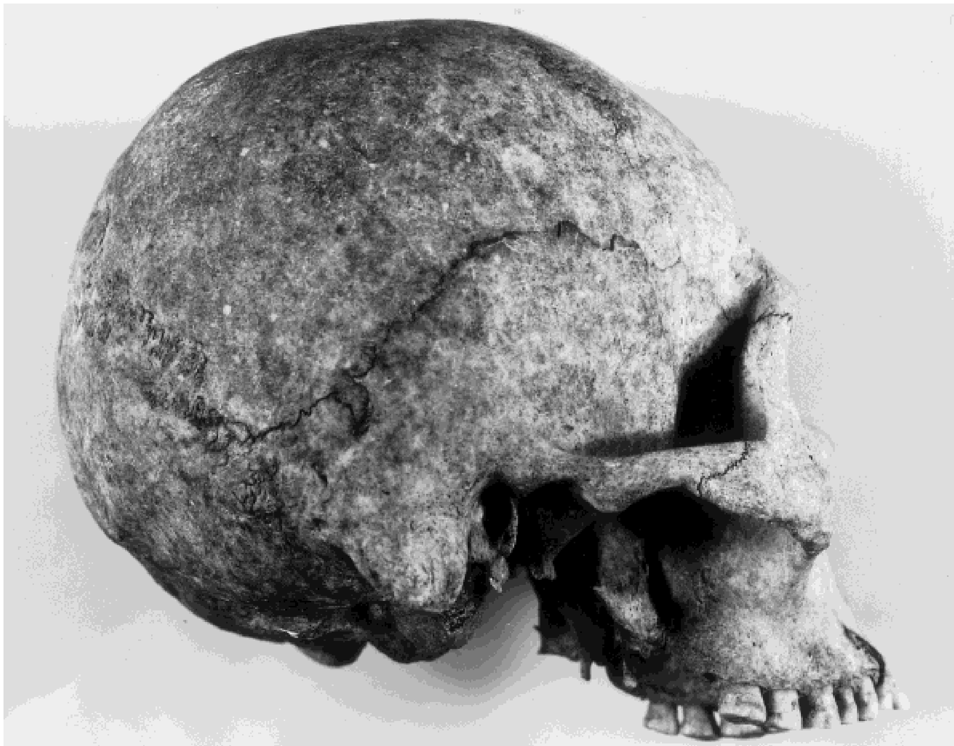

Fig. 1. Right side of the cranium.

previously reported histology of external auditory exostoses (Graham, 1979; Kemink and Graham, 1982; Pace-Balzan and Hawke, 1991).

Many researchers consider osteomas and exostoses as distinct on the basis of etiology and histology (e.g., Graham, 1979; Kemink and Graham, 1982). Distinguishing between the two is essential for understanding the confusion that underlies many previous studies. The osteoma is generally a "solitary, unilateral, bony, pedunculated tumor attached by a narrow pedicle to the tympanosquamous or tympanomastoid suture line" (Hyams et al., 1988:283). The structure of osteomas consists of a normal cortex and cancellous interior filled with fibrous tissue (Graham, 1979; Hyams et al., 1988). Clinical cases are not associated with cold water swimming (Sheehy, 1982), although osteomas are occasionally present in surfers and cold water swimmers who also have exostoses (Graham, 1979).

Auditory exostoses are generally located in the external auditory canal and are four times more common than osteomas. They are often multiple in number, bilateral and symmetric (Hyams et al., 1988). They differ in several ways from osteomas. First, although Graham (1979) reports that he has not encountered osteomas in any other location than the tympanosquamous or tympanomastoid sutures, exostoses "invariably develop along the anterior, inferior, and posterior surfaces of the tympanic bone" (Graham, 1979:570). Second, external auditory exostoses are comprised of subperiosteal lamellae with an extensive base, numerous osteocytes, and no marrow spaces (Graham, 1979; Hyams et al., 1988; Kemink and Graham, 1982; Nager, 1993; Pace-Balzan and Hawke, 1991).

Consequently, the evidence suggests that osteomas and exostoses of the ear canal have different etiologies and structures, although there are occasional reports of inter-

Fig. 2. Close-up of right side of the cranium showing exostoses.

Fig. 3. Close-up of exostoses of the left auditory meatus.

nal auditory canal exostoses attributed to the same etiology as those in the external ear (Smelt, 1984). One possibility is that osteomas are genetic and exostoses are environmental. This possibility would account for the inland cases reported by Hrdlička (1935) for Peru and other areas where populations were sufficiently removed from chronic aquatic activities. The structure of the exostosis from the Useppa Island individual is not pedunculated, exhibits no fibrous tissue, has a lamellar structure, is one of several, and is broad-based; it is an external auditory exostosis and not an osteoma.

Clinical investigators have demonstrated that swimming and other aquatic activities are associated with auditory exostoses (Adams, 1949, 1951; DiBartolomeo, 1979; Filipo et al., 1982; Harrison, 1962; Seftel, 1977; Sheehy, 1982; Umeda et al., 1989; Van Gilse, 1938). Generally, clinical studies have focused on the role of cold water and associated erythema of the auditory canal as the primary etiology for auditory exostoses (Adams, 1951; DiBartolomeo, 1985; Eike and Pedersen, 1994; Fowler and Osmun, 1942; Ohgaki et al., 1992; Oostvogel and Huttenbrink, 1992; Umeda et al., 1989; Van Gilse, 1938).

In order to determine if water temperatures in the Charlotte Harbor region would be sufficiently cold to induce the formation of osteoblastic activity resulting in exostoses, data on water temperatures from that locality measured over a 3-year period (1976–1978) were consulted (Estevez et al., 1984). Their report demonstrated that mean water temperatures below 19°C are usually present between the months of November/December and February/March. Their study further suggested that temperatures as low as 12°C were demonstrated for January, and that temperatures below 15°C were often maintained for the month February. These temperatures are within the range of some used in experimental studies (e.g., Fowler and Osmun, 1942; Van Gilse, 1938).

Fig. 4. Histological section of exostosis, approximately 70×. Arrow, external auditory exostosis; a, external circumferential lamellae; b, haversian system (osteon); c, lacunae.

However, the specific mechanisms responsible for initiating a bone formation response have not been demonstrated in these studies. Although erythema is cited as one response to cold water irrigation (Van Gilse, 1938), the role of erythema in stimulating bone formation was not discussed. Furthermore, conditions which stimulate a bone formation response are numerous and several which originate in the epithelium are well-documented.

The external auditory canal is unique in several aspects. It is the only skin-lined cul-de-sac in the human body (McLaurin, 1973). The covering epithelium is continuous from the face and incorporates the auricle, meatus, and the cartilaginous and bony canal walls. The range of pH of the surface epithelium is 5.0 to 7.8 depending on age and sex of the subject. Normal pH is therefore neutral to slightly acidic and any condition which alters the pH from acidic to basic or interrupts the continuity of the epithelium can result in otitis externa (McLaurin, 1973). Excessive exposure to water, for instance, will cause the pH to shift from acidic to alkaline and can produce macerated epithelium leading to infection. Furthermore, the auricle and external auditory canal are subject to all dermatoses that affect the human body (McLaurin, 1973).

Most commonly, pathology of the external ear is due to otitis externa, a general term indicating inflammatory skin disease of the external auditory canal and meatus (McLaurin, 1973). In his report of 62 individuals exhibiting external auditory exostoses, Sheehy (1982) reported that for 40% of these the initial symptom was otitis externa. Among the conditions that cause otitis externa are exposure to excessive cold, heat, or water contact; seborrheic dermatitis; eczema; psoriasis; contact dermatitis; sunburn; radiation; chemical burns; fungi; trauma; hemorrhages; and senile changes (McLaurin, 1973; Meyerhoff and Caruso, 1991).

The modern frequency of otitis externa is elevated during the summer months due to swimming, and the most common form is

acute otitis externa (swimmer's ear). The phenomenon is most likely due to the alteration in pH of the external auditory canal caused by water influx and by the enhanced bacterial growth caused by elevated moisture or dermal hydration in the external auditory canal. The cul-de-sac arrangement of the external auditory canal predisposes it to chronic hydration and therefore increased bacterial growth. Bacterial metabolic byproducts could then raise the pH of the epithelium, cause inflammation and invade the skin.

The formation of granulation tissue resulting from inflammation is known to provoke bone resorption (Creuss, 1982; Sadé, 1979). The formation of bone would be preceded by resorption stimulated by IL-1, TGF-β, and other inflammation products and sequelae (Gowen, 1992; Mundy and Bonewald, 1992; Takeichi et al., 1996). Inflammation of the external auditory canal is known to be caused by a host of factors including cold water, infection, trauma, any dermatological condition, or combinations of these factors.

Only a few researchers have pursued alternative hypotheses regarding the etiology of external auditory exostoses, despite clinical evidence that they can result from a variety of conditions. Any pathological state affecting the normal homeostasis of the external ear canal (e.g., otitis externa, eczema, trauma, infection, and mechanical and chemical irritation) may cause an auditory exostosis (DiBartolomeo et al., 1991). Our research indicates that it is unlikely, given the anatomical and chemical complexity of the external ear canal, that cold water can serve as an exclusive etiology for auditory exostoses. Furthermore, clinical studies indicate at least two types of bone growths in the external meatus, each having different etiologies and histological structures.

The most common etiology for external ear infection is otitis externa, which is due to a wide variety of chemical, biological, surgical, or other stimulating factors. We argue that cold water is not a sufficient exclusive etiology for external auditory exostoses given the wealth of clinical information regarding otitis externa. It is more likely that the formation of external auditory exostoses is stimulated by a wide variety of epithelial conditions that reflect hydration, pH imbalance, and other chemical, mechanical, and biological factors.

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